

Overview of the AFRL/NASA Flywheel Program

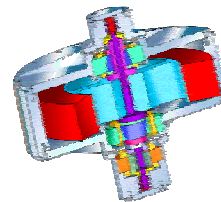
“Advanced Energy Storage for NASA and USAF missions”



NASA Glenn Research Center
Kerry McLallin



AFRL
Dr. Jerry Fausz



*Aerospace Flywheel Workshop
19 October 2000*



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Outline



- Introductory remarks
- Applications and Goals
- AFRL/NASA Program
 - Flywheel Systems
 - Research & Technology Efforts
- Concluding Remarks

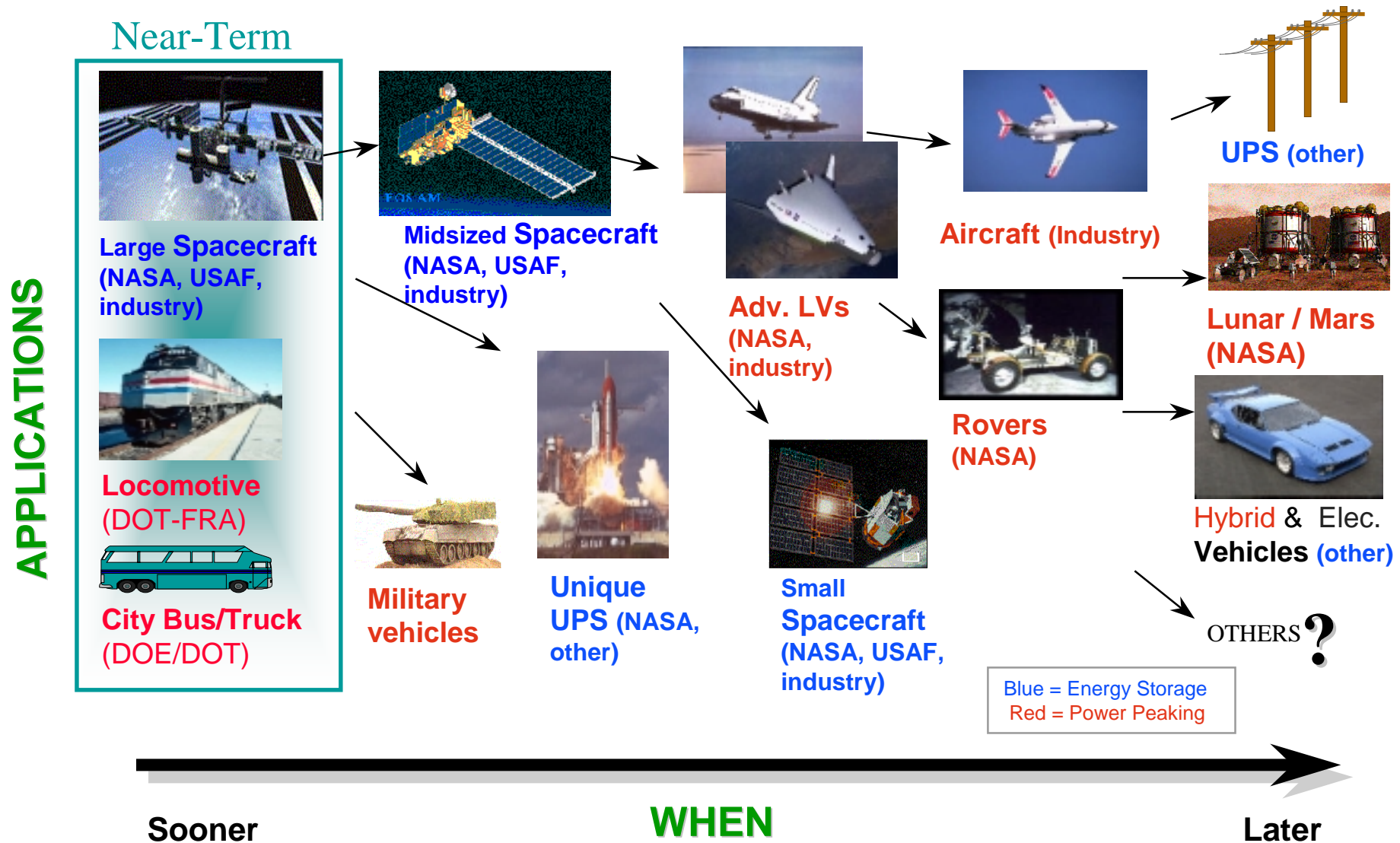


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Applications and Goals

Near-Term and Far-Term Applications



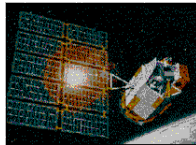
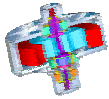


Like Batteries, No one size fits all

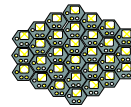


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**Small
($<500W$)**



NASA Explorer,
New Millennium,
& Discovery Classes

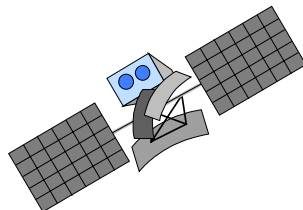
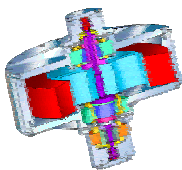


Military
Micro Sats

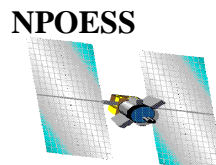


Small
Rovers

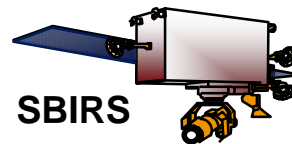
**Medium
(2-5KW)**



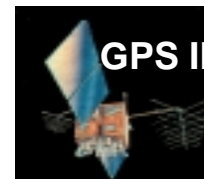
Discover II/
Starlite



NPOESS



SBIRS



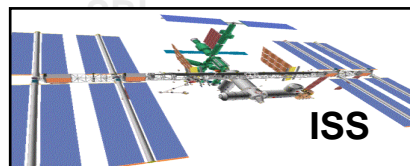
GPS II

Medium Size
Surveillance



RLV

**Large
($>10KW$)**

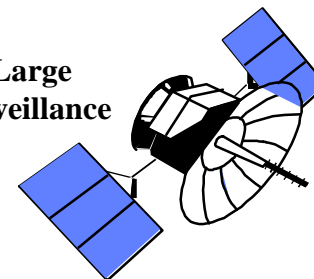


ISS

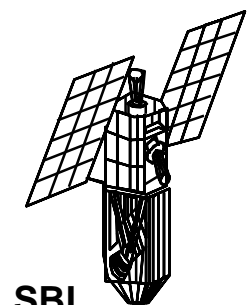


SBR

Large
Surveillance



Military Spaceplane

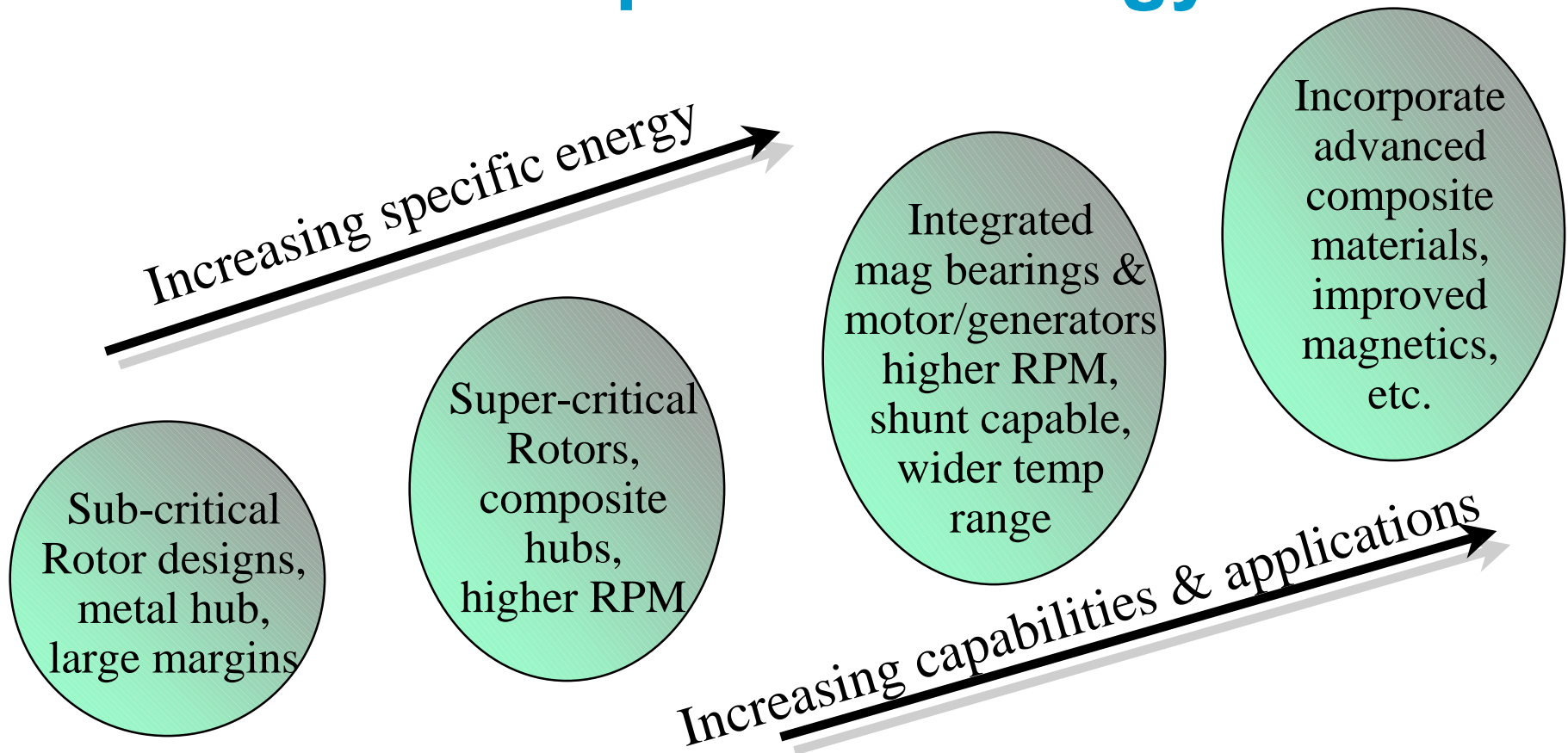


SBL



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Flywheel Technology Development Strategy





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Technology Metrics/Goals



Metric	Existing Battery Systems**	Flywheel SOA*	Flywheel Goals
Effective, Usable Specific Energy (SE) in LEO	< 3 Whr/lb	~10 Whr/lb	>20 Whr/lb (Near Term) 100 – 200 Whr/lb (Long Term)
Cycle life (at above SE levels)	~30,000	TBD (estimated at 50,000)	>75,000
Energy Storage (turn around) Efficiency	68-80%	85%	>90%
Cost	\$0.5-3M	Comparable	> 25% reduction

* Based on laboratory units extrapolated to flight configuration. Current TRL ~ 4.3-5.3

** Includes associated hardware (e.g., battery regulator)



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AFRL/NASA Program Structure



National Aerospace Flywheel Program Players



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Navy(ARL) DOT/DOE Army DARPA Terrestrial Flywheels NIST

Other
USAF

USAF
AFRL NASA
GRC

Other
NASA

American
Flywheel
Systems

OES

Flywheel
Vendors

Magne-
Motion

Moog

Primes

TRW

Boeing

Hughes

Applied
Mat'l
Tech., Inc

Ashman
Tech.

Aerospace
Corp

TCA

Foster
Miller

Test
Devices

Honeywell

USFS

Mohawk
Innovative
Tech., Inc

The
Bearing
Consultnts

PreMag
Inc

Other
Businesses

Academia/
Labs

Ook Ridge
Nat'l
Lab

Univ MD

Air Force
Institute
of Tech

Univ VA

Univ TX
CEM

Auburn

VA Tech

TX A&M

Penn St



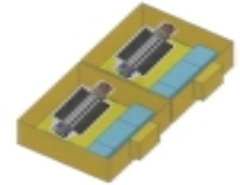
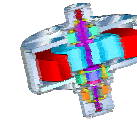
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3 Legs of the AFRL/NASA Program



SYSTEM DEVELOPMENT: *Guides Base R&T*

- FESS 1st Unit Flight on the International Space Station
- FACETS Ground demo of integrated power and attitude control system (IPACS)

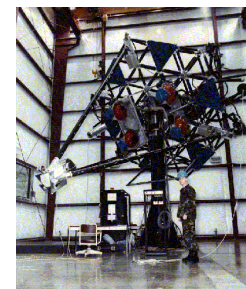


BASE R&T: *Supports System Development*

- Flywheel Testbed and Century Flywheel Development
- Component technology research
 - Bearing systems
 - Power train
 - Composite rotors
- Flywheel Rotor Safe Life Technologies Development

GOVERNMENT FACILITIES: *Enables/Enhances System and R&T Work*

- Gov't facilities and experts work with industry and academia
 - flywheel testbed, bearing test rigs, electrical test beds, NDE, etc.
 - Leverage Technology Base (Aero & Space)





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System Developments



FLYWHEEL ENERGY STORAGE SYSTEM (FESS)

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Objective

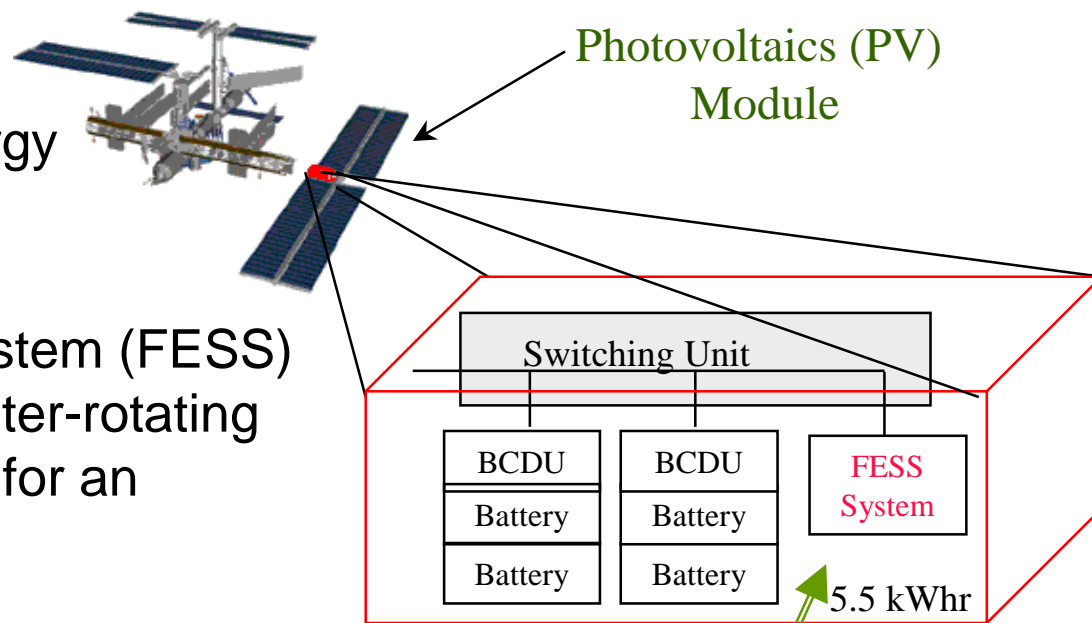
- Demonstrate flywheel energy storage, power delivery

Approach

- Deploy flywheel energy system (FESS) consisting of a pair of counter-rotating flywheel units and operate for an extended period of time

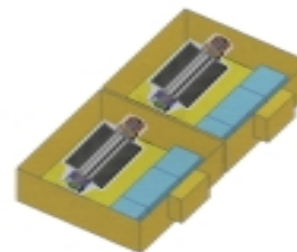
Status

- GRC/UT-CEM/TRW Team
- Flywheel Module PDR, 9-00
- FY01: FM fabrication & breadboard avionics delivery
- ISS SPEL Test in 2003
- Deploy 2006



BCDU = Battery
Charge/Discharge Unit

FESS





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Research & Technology



Flywheel System Test Bed



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Objective

Build a testbed and lab test a FES system to gain experience w/ energy storage & single axis torque control as a foundation for mid-size wheel development

Approach

U.S. Flywheels/TRW Development Units(2)

- ~ 500 Whr
- Magnetic & mechanical bearings

NASA GRC Testbed

- dSPACE based developmental controls
- Single unit and air table capability



Plans

- Support FESS Development
- Demo single axis momentum transfer (2 Units)
- Support Century Flywheel technology evaluation

Status

- Unit #1 in test at GRC testbed facility
- Hardware upgrades in progress for 2 units



Century Flywheel Program



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- **Objective**

DEVELOP TECHNOLOGY DEMONSTRATOR THAT MEETS THE NEEDS OF "MID-SIZE" LEO SPACECRAFT (~700 W to ~4 KW) WITH ENERGY STORAGE REQUIREMENTS OF 300-700 WHrs

- **Approach**

- PERFORMANCE GOALS ARE HIGH SPECIFIC ENERGY, HIGH EFFICIENCY AND LOW COST IN AN "IPACS" CONFIGURATION
- A PHASED IMPLEMENTATION OF ADVANCED TECHNOLOGIES INTO A TARGET SYSTEM PROTOTYPE FOR SATELLITE APPLICATION
- COMPONENT TECHNOLOGY DEVELOPMENT IS LEVERAGED WITH NASA/AFRL NRA'S, SBIR'S AND CCDS GRANT'S

- **Plans In FY01**

- DEFINE MISSION/SATELLITE REQUIREMENTS AND FLOW DOWN TO FLYWHEEL SYSTEM AND COMPONENTS IN COOPERATION WITH MISSION CENTERS AND PRIMES
- BEGIN CONCEPTUAL DESIGN OF PROTOTYPE
- EVALUATE COMPONENT TECHNOLOGIES FOR USE IN FIRST UNIT

- **Status**

- INITIATING CONTACT WITH MISSION CENTERS AND PRIMES



Base R&T Efforts for FY01

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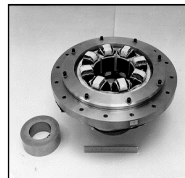


System Research

- Integrated System Design Tool
- System Momentum Control
- Real Time Simulation

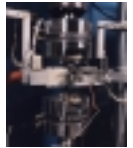
Component Research

- Magnetic Bearings
 - Advanced Bearing Control
 - Passive (Repulsive) Bearings
- Power Train
 - Optimized Mtr/Gen Control
 - Advanced Mtr/Gen
 - High Speed Concepts



Composite Rotors

- Rotor Safe-Life Program
 - Life Prediction Development
 - Material Testing
 - Rotor Cyclic Spin Testing
 - NDE Techniques
- Health Monitoring Development
- Composite Rotor/Hub Development
- Century-Class Rotor Design





Concluding Remarks



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- A broad range of NASA/USAF applications exist for which Aerospace Flywheels are a significantly enhancing or enabling technology – FES, IPACS, UPS, Peaking, Vehicles
- Exciting developments planned in 2001:
 - Rotor Safe-Life Program – Implement Working Group
 - Flywheel Testbed – 2 unit momentum mode test
 - FACETS Phase 2
 - FESS Development Flywheel Module Build
- Technology efforts will increasingly focus on smaller flywheels
 - Many missions need “century class” flywheels (100’s of whrs)
 - The Century Flywheel Program will provide direction and focus to technology development
- The AFRL/NASA Aerospace Flywheel Program will continue to cooperate with other government agencies and to leverage other program opportunities such as; NRA’s, SBIR’s, NASA CCDS



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Backup Slides



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Aerospace Flywheel Challenges



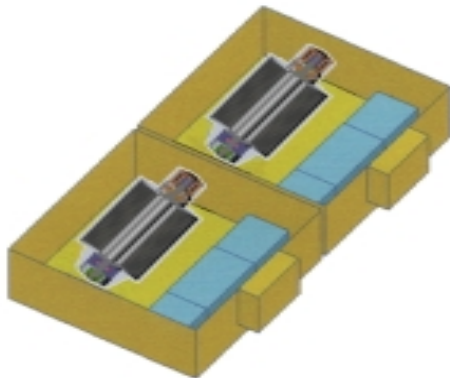
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Flywheel Energy Systems



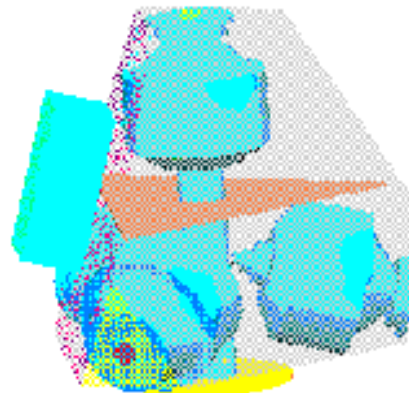
Flywheel Energy Storage (FES)

- 2, counter-rotating Flywheels
- Energy storage
- Replace some Power Management and Distribution (PMAD) functions



Integrated Power & Attitude Control System (IPACS)

- Array of ≥ 2 FWs
- Energy storage & Attitude control torque
- Replace some PMAD



*E.g., A
Tetrahedral
Arrangement
of 4 FWs, or
4 pairs of
FWs*



Flywheel Components



Flywheel System:

Component interaction,
Space environment, Controls,
(micrometeoroids, etc).

Enclosure:

lightweight but stiff,
spacecraft mechanical
and thermal interface

Motor/Generator:

Reliability, efficiency

Thermal:

passive heat rejection,
Esp.: Gimbal mounted
concepts

Magnetic Bearings:

Controls & losses are
the key risk areas,
also fault tolerance
& design for IPACS

Rotor (Rim, Hub Shaft):

High specific energy
(super critical design?),
Fatigue Life & “creep”,
safety W/O containment

Auxiliary Bearings:

High speed, high impact, life
Esp.: Launch environment

Electronics:

IPACS control algorithms,
packaging for lightweight

